



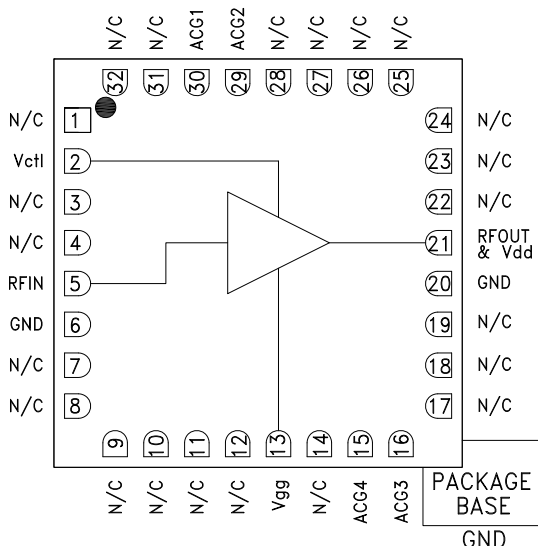
## MZ OPTICAL MODULATOR DRIVER, DC - 20 GHz

### Typical Applications

The HMC870LC5 is ideal for:

- 10 Gbps NRZ MZ & Low  $V_{\text{TI}}$  Modulator Driver
- 10 Gbps RZ Transmission
- 40 Gbps DQPSK
- Broadband Gain Block for Test & Measurement Equipment
- Military & Space

### Functional Diagram



### Features

- Wide Supply Range from 3.3V to 7V
- Adjustable Output Amplitude: 2.5 to 8 Vp-p
- Low Additive RMS Jitter, <300 fs
- Low DC Power Consumption  
1W for Vout = 8 Vp-p at Vdd = 7V
- Cross Point Adjustment
- 32 Lead 5x5mm SMT Package: 25mm<sup>2</sup>

### General Description

The HMC870LC5 is a GaAs MMIC pHEMT Distributed Driver Amplifier packaged in a leadless 5x5 mm surface mount package which operates between DC and 20 GHz. The amplifier provides 17 dB of gain, 8Vp-p saturated output swing and features output swing cross point adjustment. Gain flatness is excellent at  $\pm 0.5$  dB as well as very low additive RMS jitter of 300 fs for 10 Gbps operation. HMC870LC5 provides Metro and Long Haul designers with scalable power dissipation for varying output drive requirements. (<0.4W at Vout = 3.6 Vp-p and <1W at Vout = 8.5 Vp-p) The HMC870LC5 has a very wide supply (Vdd) operating range from +3.3V to +7V, and the RF I/Os are internally matched to 50 Ohms.

### Electrical Specifications, $T_A = +25^\circ\text{C}$ , $V_{\text{dd}} = 7\text{V}$ , $V_{\text{ctl}} = 1\text{V}$ , $I_{\text{dd}} = 165\text{mA}^*$

| Parameter                                  | Conditions              | Min. | Typ.     | Max.  | Units                |
|--|-------------------------|------|----------|-------|----------------------|
| Gain                                       | Frequency = 1 - 8 GHz   | 14   | 17.5     |       | dB                   |
|  | Frequency = 8 - 16 GHz  | 13   | 16.5     |       | dB                   |
|  | Frequency = 16 - 20 GHz | 12   | 16       |       | dB                   |
| Small Signal Bandwidth                     | 3-dB cutoff             |      | 20       |       | GHz                  |
| Input Return Loss                          | Frequency = 1 - 10 GHz  |      | 20       |       | dB                   |
|  | Frequency = 10 - 20 GHz |      | 15       |       | dB                   |
| Output Return Loss                         | Frequency = 1 - 10 GHz  |      | 20       |       | dB                   |
|  | Frequency = 10 - 20 GHz |      | 15       |       | dB                   |
| Gain Variation over Temperature            | Frequency = 1 - 10 GHz  |      | 0.015    | 0.02  | dB/ $^\circ\text{C}$ |
|  | Frequency = 10 - 20 GHz |      | 0.032    | 0.045 | dB/ $^\circ\text{C}$ |
| Group Delay Variation                      | Frequency = 1 - 12 GHz  |      | $\pm 15$ |       | ps                   |
| Saturated Output Power (P <sub>sat</sub> ) | Frequency = 1 - 12 GHz  |      | 24       |       | dBm                  |
|  | Frequency = 12 - 20 GHz |      | 23       |       | dBm                  |

\* Adjust Vg between -2V to 0V to achieve Idd = 165 mA typical.

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**MZ OPTICAL MODULATOR  
DRIVER, DC - 20 GHz**
**Electrical Specifications,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = 7\text{V}$ ,  $V_{CTL} = 1\text{V}$ ,  $I_{DD} = 165\text{mA}$ \* Continued**

| Parameter  | Conditions  | Min.     | Typ.     | Max. | Units      |
|--|---|----------|----------|------|------------|
| Output Power for 1 dB Compression (P1dB)                         | Frequency = 1 - 12 GHz<br>Frequency = 12 - 20 GHz | 19<br>18 | 22<br>21 |      | dBm<br>dBm |
| Rise Time <sup>[1]</sup>   | 20% - 80%   |          | 20       |      | ps         |
| Fall Time <sup>[1]</sup>   | 20% - 80%   |          | 20       |      | ps         |
| Additive RMS Jitter <sup>[2]</sup>                               |   |          |          | 300  | fs         |
| Supply Current (I <sub>DD</sub> ) (V <sub>GG</sub> = -0.6V Typ.) |   |          | 165      |      | mA         |
| Bias Current Adjust (V <sub>GG</sub> )                           |   | -2       |          | 0    | V          |
| Output Voltage Adjust (V <sub>CTL</sub> )                        |   | 0        |          | 2    | V          |

[1] Data input = 22.5 Gbps NRZ PRBS 2<sup>23</sup>-1 pattern, 1.2 V<sub>p-p</sub>.

[2] RMS jitter is calculated with 22.5 Gbps 10101... pattern.

\* Adjust V<sub>GG</sub> between -2V to 0V to achieve I<sub>DD</sub> = 165 mA typical.

**Electrical Specifications,  $T_A = +25^\circ\text{C}$ ,  $V_{DD} = 5\text{V}$ ,  $V_{CTL} = 1\text{V}$ ,  $I_{DD} = 140\text{mA}$ \***

| Parameter  | Conditions   | Min.             | Typ.                 | Max.          | Units          |
|--|--|------------------|----------------------|---------------|----------------|
| Gain   | Frequency = 1 - 8 GHz<br>Frequency = 8 - 16 GHz<br>Frequency = 16 - 20 GHz | 14<br>13.5<br>12 | 17.5<br>17.0<br>16.5 |               | dB<br>dB<br>dB |
| Small Signal Bandwidth   | 3-dB cutoff  |                  | 20                   |               | GHz            |
| Input Return Loss  | Frequency = 1 - 10 GHz<br>Frequency = 10 - 20 GHz                          |                  | 20<br>15             |               | dB<br>dB       |
| Output Return Loss   | Frequency = 1 - 10 GHz<br>Frequency = 10 - 20 GHz                          |                  | 15<br>10             |               | dB<br>dB       |
| Gain Variation over Temperature                                  | Frequency = 1 - 10 GHz<br>Frequency = 10 - 20 GHz                          |                  | 0.016<br>0.029       | 0.02<br>0.045 | dB/°C<br>dB/°C |
| Group Delay Variation  | Frequency = 1 - 12 GHz   |                  | ±15                  |               | deg            |
| Saturated Output Power (P <sub>sat</sub> )                       | Frequency = 1 - 12 GHz<br>Frequency = 12 - 20 GHz                          |                  | 22.5<br>22           |               | dBm<br>dBm     |
| Output Power for 1 dB Compression (P1dB)                         | Frequency = 1 - 12 GHz<br>Frequency = 12 - 20 GHz                          | 18<br>17         | 20.5<br>20           |               | dBm<br>dBm     |
| Rise Time <sup>[1]</sup>   | 20% - 80%  |                  | 20                   |               | ps             |
| Fall Time <sup>[1]</sup>   | 20% - 80%  |                  | 20                   |               | ps             |
| Additive RMS Jitter <sup>[2]</sup>                               |  |                  |                      | 300           | fs             |
| Supply Current (I <sub>DD</sub> ) (V <sub>GG</sub> = -0.6V Typ.) |  |                  | 140                  |               | mA             |
| Bias Current Adjust (V <sub>GG</sub> )                           |  | -2               |                      | 0             | V              |
| Output Voltage Adjust (V <sub>CTL</sub> )                        |  | 0                |                      | 2             | V              |

[1] Data input = 22.5 Gbps NRZ PRBS 2<sup>23</sup>-1 pattern, 1.2 V<sub>p-p</sub>.

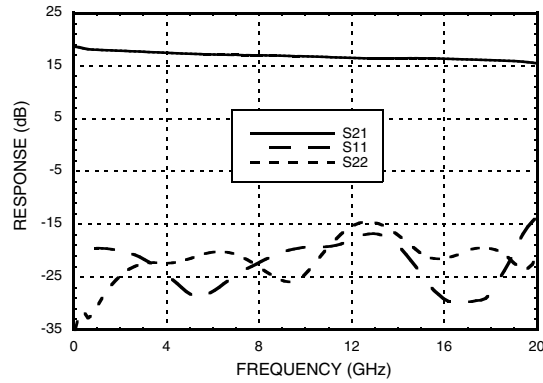
[2] RMS jitter is calculated with 22.5 Gbps 10101... pattern.

\* Adjust V<sub>GG</sub> between -2V to 0V to achieve I<sub>DD</sub> = 140 mA typical.

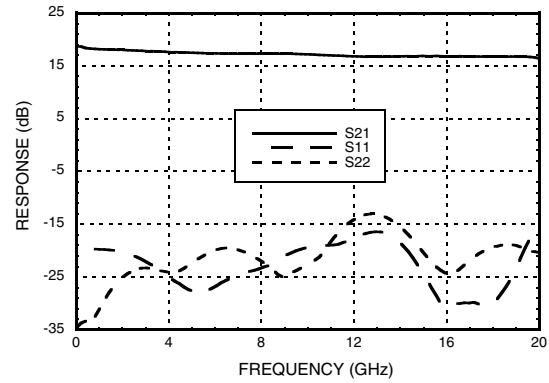


**MZ OPTICAL MODULATOR  
DRIVER, DC - 20 GHz**

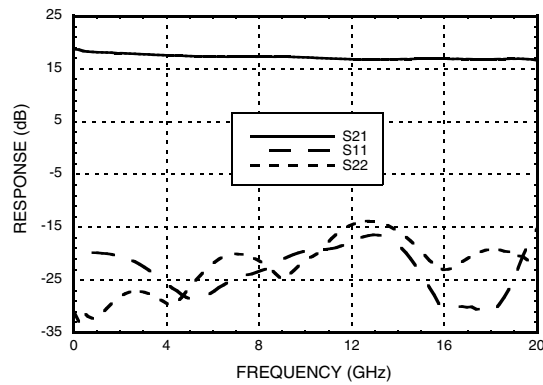
**Gain & Return Loss @ Vdd = 7V**



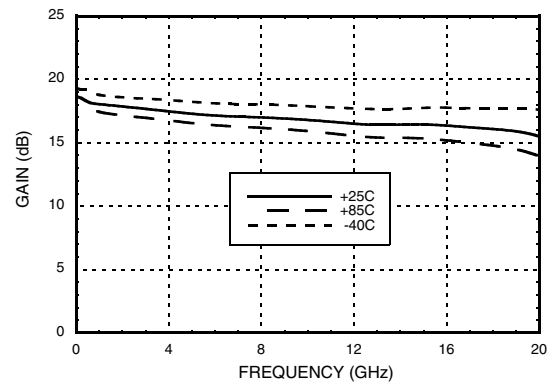
**Gain & Return Loss @ Vdd = 5V**



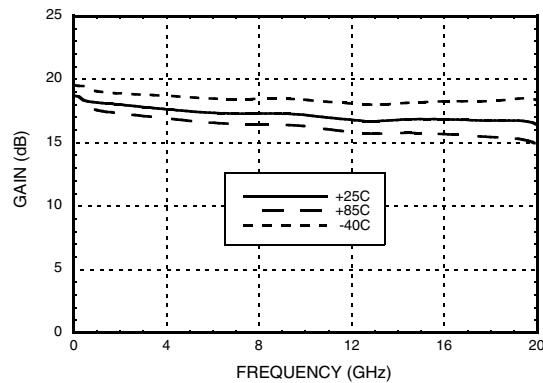
**Gain & Return Loss @ Vdd = 3.3V**



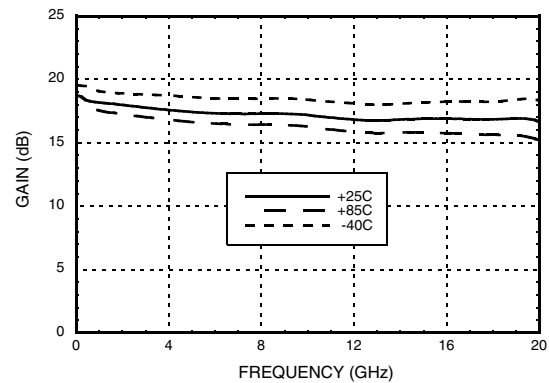
**Gain vs. Temperature @ Vdd = 7V**

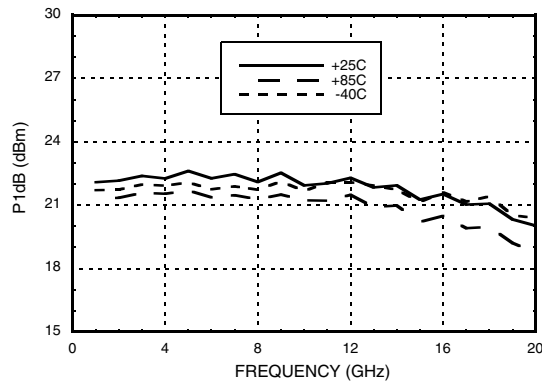
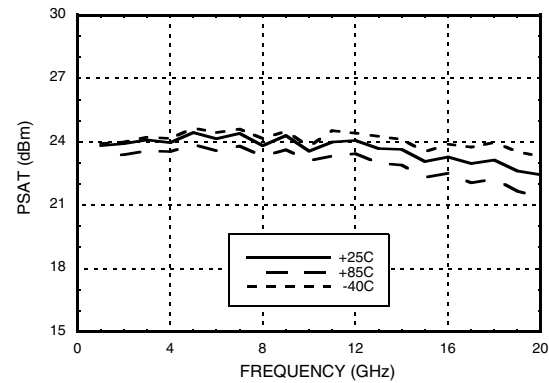
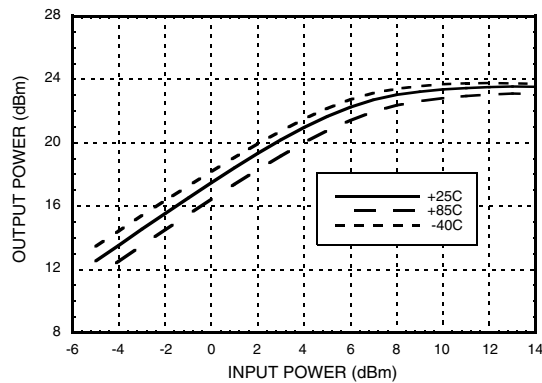
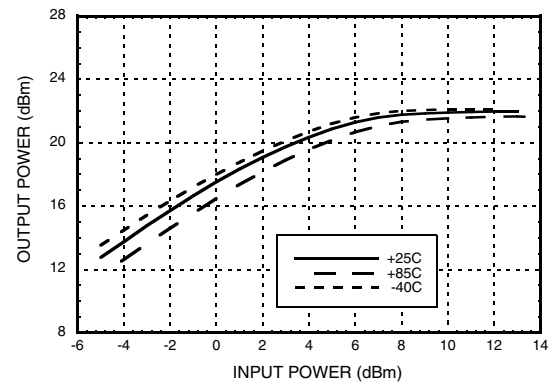
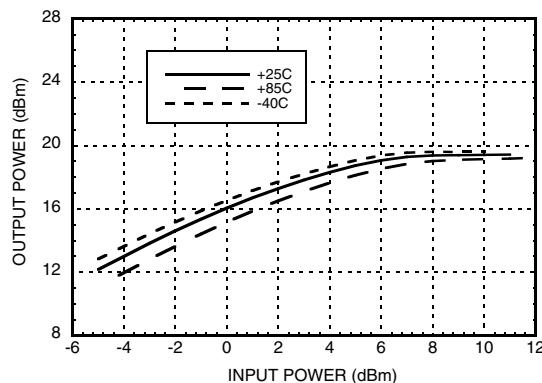
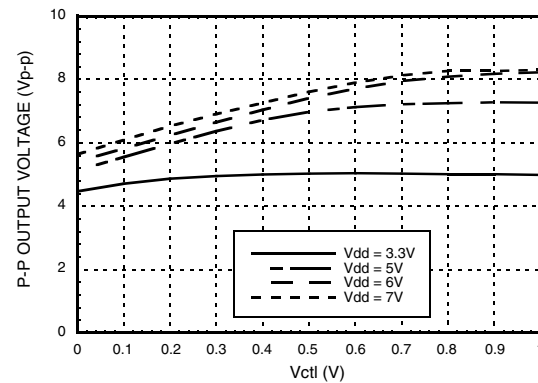


**Gain vs. Temperature @ Vdd = 5V**

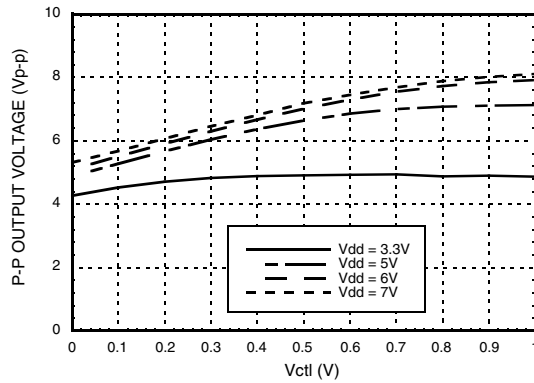
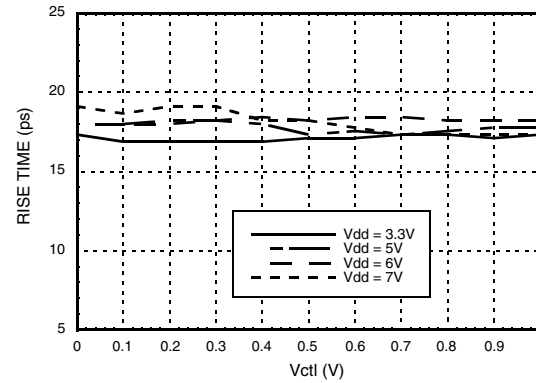
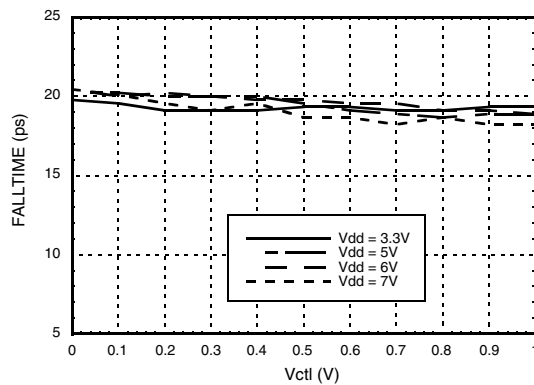
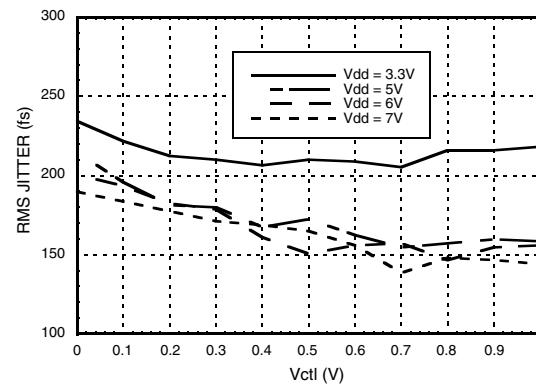
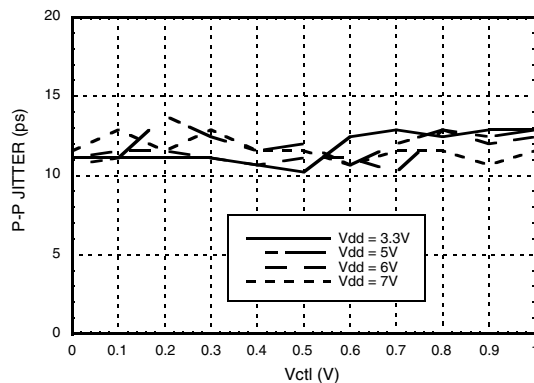
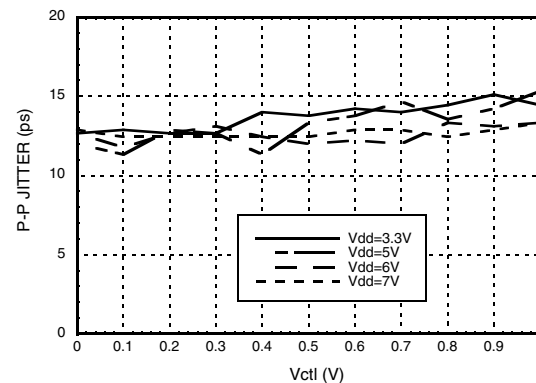


**Gain vs. Temperature @ Vdd = 3.3V**



**MZ OPTICAL MODULATOR  
DRIVER, DC - 20 GHz**
**P1dB vs. Temperature @ Vdd = 7V**

**Psat vs. Temperature @ Vdd = 7V**

**Output Power vs. Input Power  
@ 10 GHz, Vdd = 7V**

**Output Power vs. Input Power  
@ 10 GHz, Vdd = 5V**

**Output Power vs. Input Power  
@ 10 GHz, Vdd = 3.3V**

**Peak-to-Peak Output Voltage vs.  
Vdd @ 11.25 Gbps<sup>[1]</sup>**


[1] Data input = 11.25 Gbps NRZ PRBS 2<sup>23</sup>-1 pattern, 1.2 Vp-p.

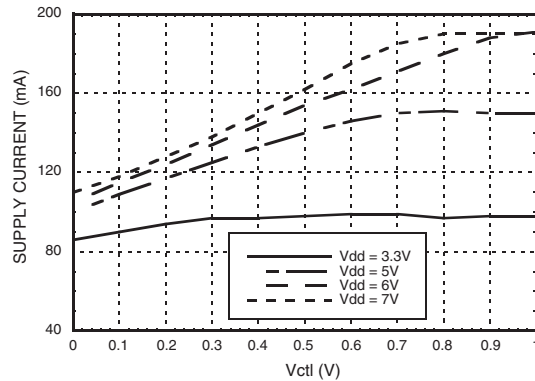

**MZ OPTICAL MODULATOR  
DRIVER, DC - 20 GHz**
**Peak-to-Peak Output Voltage vs. Vdd @  
22.5 Gbps <sup>[1]</sup>**

**Rise Time vs. Vdd @ 22.5 Gbps <sup>[1]</sup>**

**Fall Time vs. Vdd @ 22.5 Gbps <sup>[1]</sup>**

**RMS Jitter vs. Vdd @ 22.5 Gbps <sup>[2]</sup>**

**Peak-to-Peak Jitter vs. Vdd @ 11.25 Gbps <sup>[3][4]</sup>**

**Peak-to-Peak Jitter vs. Vdd @ 22.5 Gbps <sup>[1][4]</sup>**


[1] Data input = 22.5 Gbps NRZ PRBS 2<sup>23</sup>-1 pattern, 1.2 Vp-p.

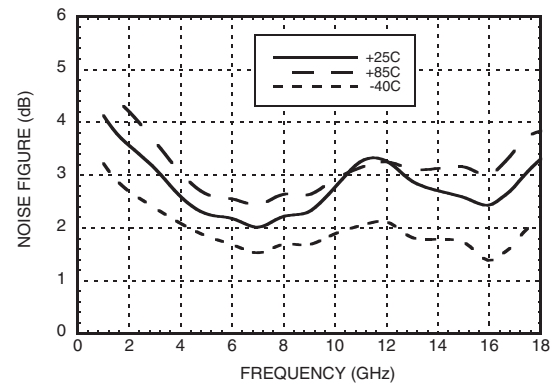
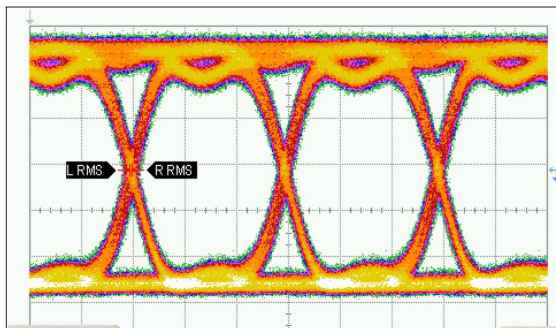
[2] RMS jitter is measured with 22.5 Gbps 10101... pattern.

[3] Data input = 11.25 Gbps NRZ PRBS 2<sup>23</sup>-1 pattern, 1.2 Vp-p.

[4] Source jitter was not de-embedded.

**MZ OPTICAL MODULATOR  
DRIVER, DC - 20 GHz**
**Supply Current vs. Vdd @ 22.5 Gbps [1]**


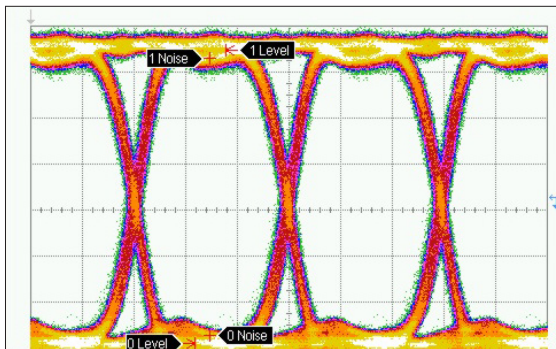
[1] Data Input = 22.5 Gbps NRZ PRBS 223-1 pattern, 1.2 Vp-p

**Noise Figure vs. Temperature @ Vdd = 7V**

**11.25 Gbps NRZ Output Eye Diagram**


|               | Measurements |       |       | Units |
|---------------|--------------|-------|-------|-------|
|               | Current      | Min   | Max   |       |
| Eye Amplitude | 3.6          | 3.6   | 3.6   | V     |
| Rise Time     | 20           | 20    | 20    | ps    |
| Fall Time     | 21.33        | 20.67 | 22    | ps    |
| Jitter RMS    | 1.893        | 1.87  | 2.072 | ps    |

Time scale: 30.0 ps/div  
Amplitude scale: 762 mV/div

Vdd = 3.3V, Vin: 11.25 Gbps NRZ PRBS 2<sup>31</sup>-1, 0.5 Vp-p  
Vout: 3.6Vp-p  
Vctl = 1V

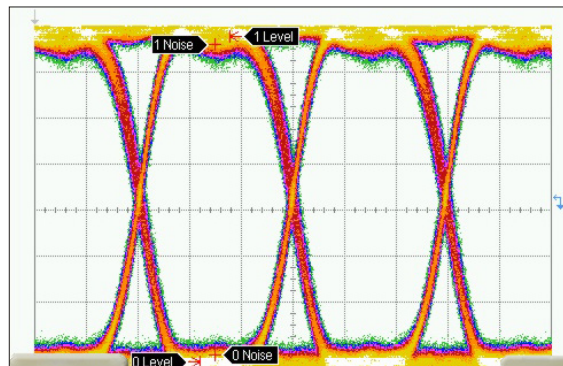
**11.25 Gbps NRZ Output Eye Diagram**


|               | Measurements |       |       | Units |
|---------------|--------------|-------|-------|-------|
|               | Current      | Min   | Max   |       |
| Eye Amplitude | 7.47         | 7.47  | 7.47  | V     |
| SNR           | 17.97        | 17.88 | 18.12 | V/V   |

Time scale: 30.0 ps/div  
Amplitude scale: 1.17 V/div

Vdd = 5V, Vin: 11.25Gbps NRZ PRBS 2<sup>31</sup>-1, 1.2V p-p,  
Vout: 7.5Vp-p  
Vctl = 1V

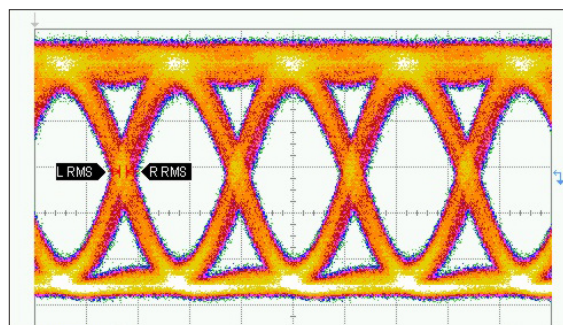



**MZ OPTICAL MODULATOR  
DRIVER, DC - 20 GHz**
**11.25 Gbps NRZ Output Eye Diagram (Continued)**


|               | Measurements |       |       |       |
|---------------|--------------|-------|-------|-------|
|               | Current      | Min   | Max   | Units |
| Eye Amplitude | 8.26         | 8.26  | 8.27  | V     |
| SNR           | 22.35        | 22.26 | 22.51 | V/V   |

Time scale: 30.0 ps/div  
Amplitude scale: 1.17 V/div

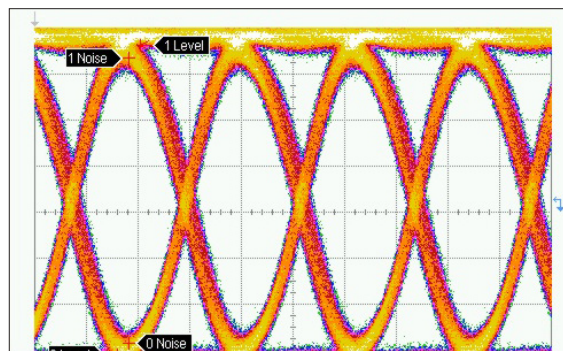
Vdd = 7V, Vin: 11.25Gbps NRZ PRBS 2<sup>31</sup>-1, 1.2V p-p,  
Vout: 8.3Vp-p  
Vctl = 1V

**22.5 Gbps NRZ Output Eye Diagram**


|               | Measurements |       |       |       |
|---------------|--------------|-------|-------|-------|
|               | Current      | Min   | Max   | Units |
| Eye Amplitude | 3.53         | 3.53  | 3.54  | V     |
| Rise Time     | 18.22        | 17.33 | 18.22 | ps    |
| Fall Time     | 20.44        | 19.56 | 20.89 | ps    |
| Jitter RMS    | 2.417        | 2.187 | 2.422 | ps    |

Time scale: 20.0 ps/div  
Amplitude scale: 762 mV/div

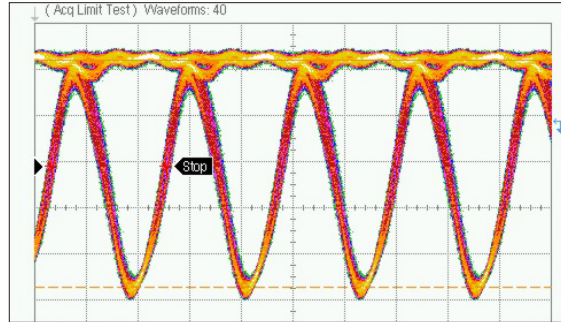
Vdd = 3.3V, Vin: 22.5Gbps NRZ PRBS 2<sup>31</sup>-1, 0.5V p-p,  
Vout: 3.5Vp-p  
Vctl = 1V

**22.5 Gbps NRZ Output Eye Diagram**


|               | Measurements |       |       |       |
|---------------|--------------|-------|-------|-------|
|               | Current      | Min   | Max   | Units |
| Eye Amplitude | 7.85         | 7.84  | 7.85  | V     |
| SNR           | 13.74        | 13.69 | 14.07 | V/V   |

Time scale: 20.0 ps/div  
Amplitude scale: 1.17 V/div

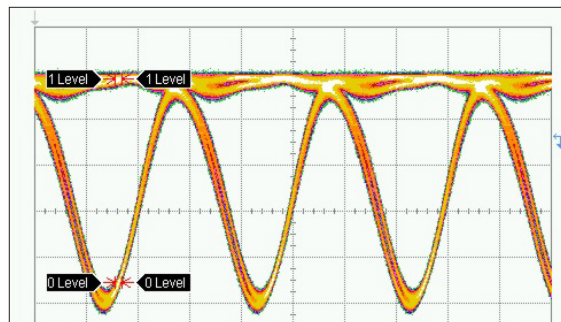
Vdd = 7V, Vin: 22.5Gbps NRZ PRBS 2<sup>31</sup>-1, 1.2 V p-p,  
Vout: 7.9Vp-p  
Vctl = 1V

**MZ OPTICAL MODULATOR  
DRIVER, DC - 20 GHz**
**11.25 Gbps RZ Output Eye Diagram**


| Measurements |         |       |
|--------------|---------|-------|
|              | Current | Units |
| Jitter RMS   | 1.93    | ps    |
| Bit Rate     | 11.2    | Gb/s  |

Time scale: 40.0 ps/div  
Amplitude scale: 1.22 V/div

Vdd = 3.3V, Vin: 11.25Gbps RZ PRBS 2<sup>31</sup>-1, 0.3V p-p,  
Vout: 2.9Vp-p  
Vctl = 1V

**11.25 Gbps RZ Output Eye Diagram**


| Measurements  |         |       |       |       |
|---------------|---------|-------|-------|-------|
|               | Current | Min   | Max   | Units |
| Duty Cycle    | 51.5    | 50.4  | 57.1  | %     |
| SNR           | 20.85   | 13.35 | 20.96 | V/V   |
| Jitter RMS    | 1.753   | 1.689 | 1.795 | ps    |
| Eye Amplitude | 2.85    | 2.37  | 2.86  | V     |

Time scale: 30.0 ps/div  
Amplitude scale: 647 mV/div

Vdd = 5V, Vin: 11.25Gbps RZ PRBS 2<sup>31</sup>-1, 1.2V p-p,  
Vout: 6Vp-p  
Vctl = 1V

**Absolute Maximum Ratings**

|   |                     |
|---|---------------------|
| Drain Bias Voltage (Vdd)  | +9V                 |
| Gate Bias Voltage (Vgg)   | -2V to 0V           |
| Control Bias Voltage (Vctl)   | (Vdd -7) to Vdd (V) |
| RF Input Power (RFIN)(Vdd = +7 Vdc)                                       | +23 dBm             |
| Channel Temperature   | 175 °C              |
| Continuous P <sub>diss</sub> (T = 85 °C)<br>(derate 24 mW/°C above 85 °C) | 1.5 W               |
| Thermal Resistance<br>(channel to ground paddle)                          | 59.4 °C/W           |
| Storage Temperature   | -65 to +150 °C      |
| Operating Temperature   | -40 to +85 °C       |
| ESD Sensitivity (HBM)   | Class 1A            |

**Typical Supply Current vs. Vdd\***

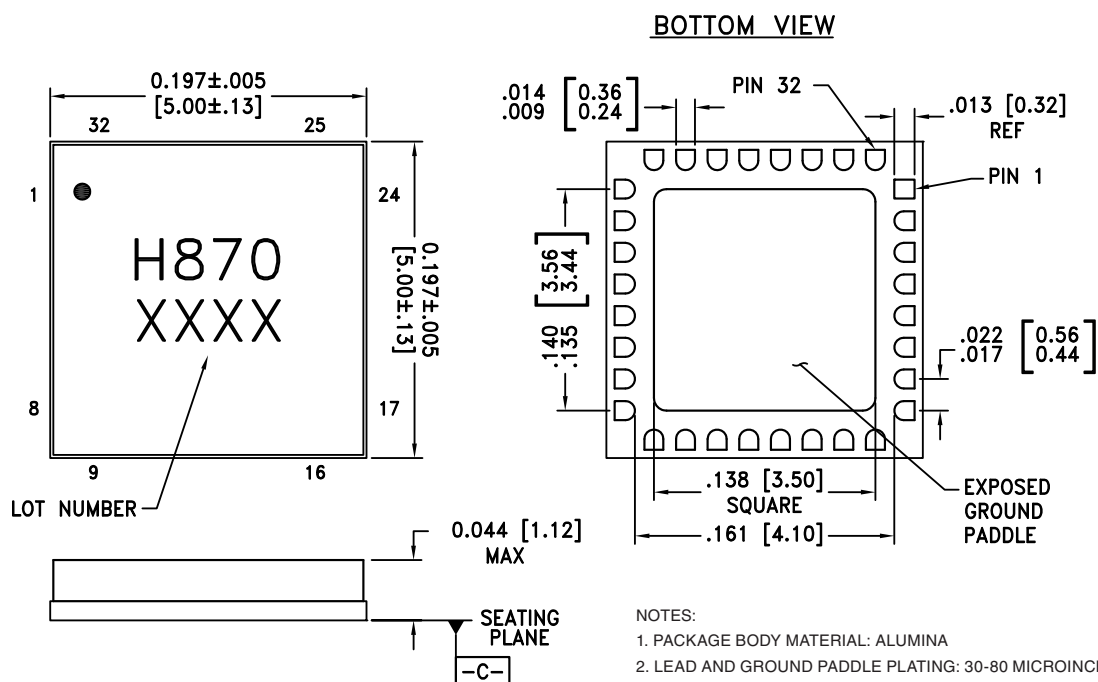
| Vdd (V) | Idd (mA)* | Power<br>Dissipation (W) |
|---------|-----------|--------------------------|
| +3.3    | 100       | 0.33                     |
| +5.0    | 140       | 0.70                     |
| +6.0    | 160       | 0.96                     |
| +7.0    | 165       | 1.115                    |

\* Adjust Vgg between -2V to 0V to achieve Idd shown.



**ELECTROSTATIC SENSITIVE DEVICE  
OBSERVE HANDLING PRECAUTIONS**



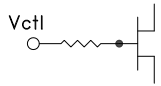
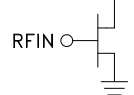

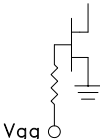
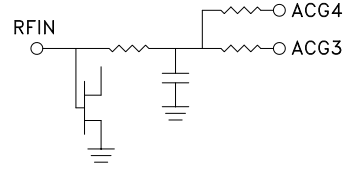
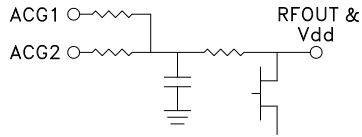

**MZ OPTICAL MODULATOR  
DRIVER, DC - 20 GHz**
**Outline Drawing****Package Information**

| Part Number | Package Body Material | Lead Finish      | MSL Rating          | Package Marking <sup>[2]</sup> |
|-------------|-----------------------|------------------|---------------------|--------------------------------|
| HMC870LC5   | Alumina, White        | Gold over Nickel | MSL3 <sup>[1]</sup> | H870<br>XXXX                   |

[1] Max peak reflow temperature of 260 °C

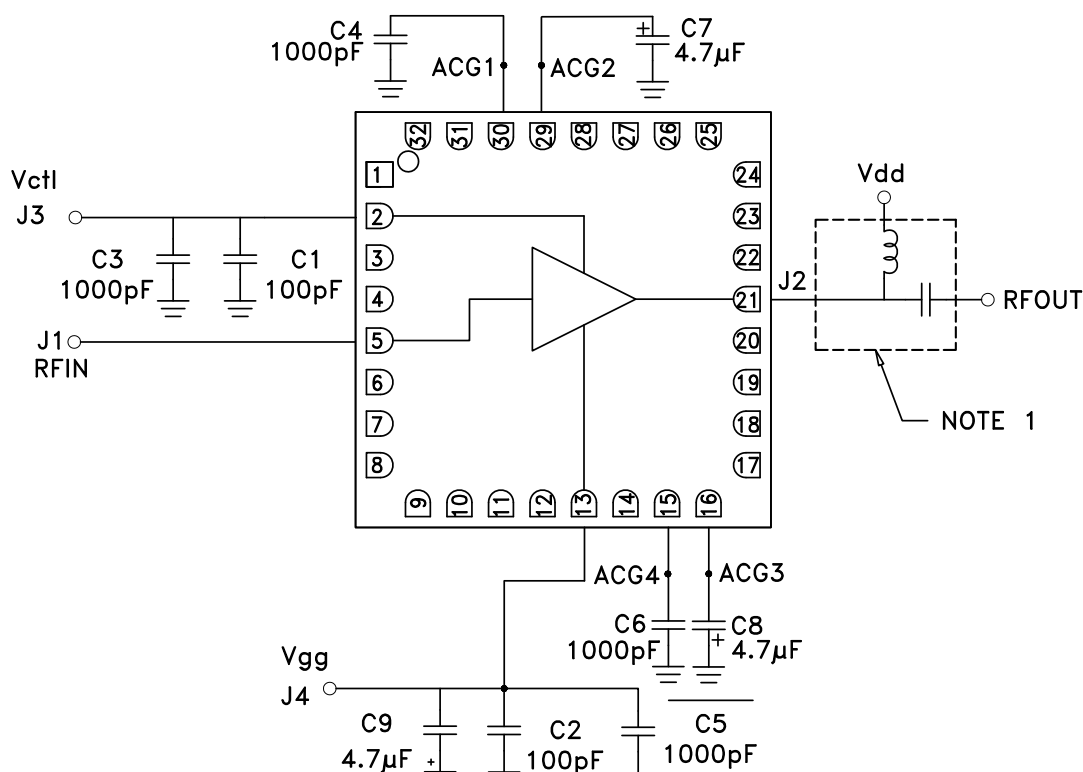
[2] 4-Digit lot number XXXX

## Pin Descriptions

| Pin Number                                    | Function    | Description  | Interface Schematic   |
|---|-------------|--|---|
| 1, 3, 4, 7 - 12, 14, 17 - 19, 22 - 28, 31, 32 | N/C         | The pins are not connected internally; however, all data shown herein was measured with these pins connected to RF/DC ground externally. |   |
| 2   | Vctl        | Output voltage swing adjustment. +1V should be applied to Vctl for nominal operation.  |    |
| 5   | RFIN        | This pin is DC coupled and matched to 50 Ohms.   |    |
| 6, 20   | GND         | RF/DC Ground. These pins and the package base must be connected to RF/DC ground.   |    |
| 13  | Vgg         | Gate Control for amplifier.  |    |
| 15  | ACG4        | Low frequency termination. Attach bypass capacitor per application circuit herein.   |   |
| 16  | ACG3        |  |   |
| 21  | RFOUT & Vdd | RF output for amplifier. Connect the DC bias (Vdd) network to provide drain current (Idd). See application circuit herein.               |  |
| 29  | ACG2        | Low frequency termination. Attach bypass capacitor per application circuit herein.   |   |
| 30  | ACG1        |  |   |

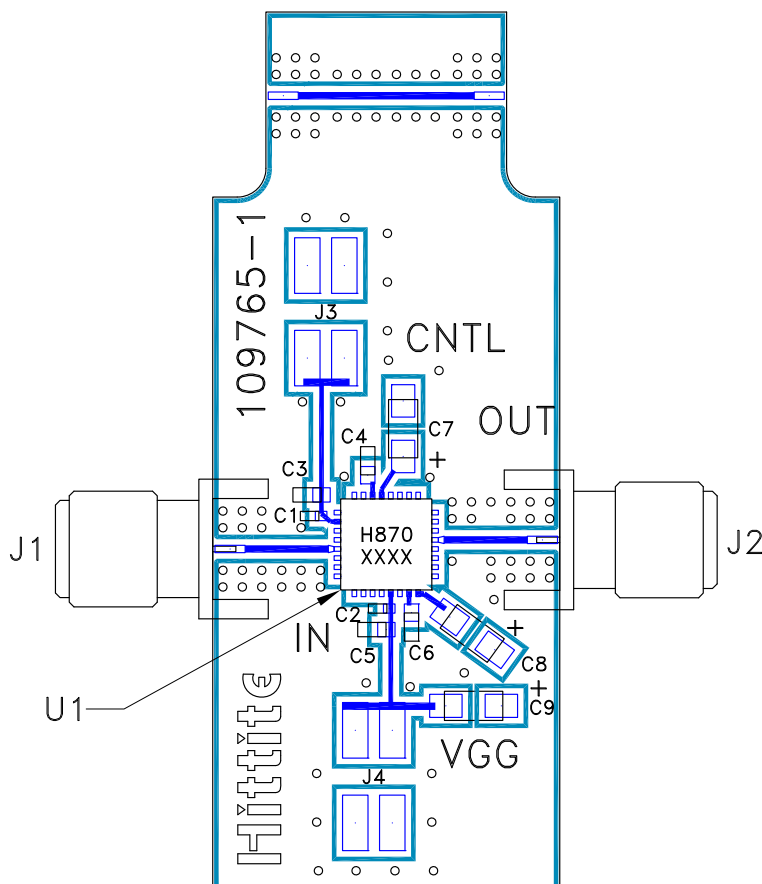


## Application Circuit



**NOTE 1:** Drain Bias (Vdd) must be applied through a broadband bias tee or external bias network.

For price, delivery, and to place orders: Analog Devices, Inc.,  
One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106  
Phone: 781-329-4700 • Order online at [www.analog.com](http://www.analog.com)  
Application Support: Phone: 1-800-ANALOG-D

**Evaluation PCB**

**List of Materials for Evaluation PCB 108347 <sup>[1]</sup>**

| Item               | Description                     |
|--------------------|---------------------------------|
| J1 - J2            | PCB Mount SMA Connector         |
| J3 - J4            | 2mm Molex Header                |
| C1, C2             | 100 pF Capacitor, 0402 Pkg.     |
| C3 - C6            | 1000 pF Capacitor, 0603 Pkg.    |
| C7 - C9            | 4.7 $\mu$ F Capacitor, Tantalum |
| U1                 | HMC870LC5, Modulator Driver     |
| PCB <sup>[2]</sup> | 109765 Evaluation PCB           |

[1] Reference this number when ordering complete evaluation PCB

[2] Circuit Board Material: Arlon 25FR or Rogers 4350

The circuit board used in the application should use RF circuit design techniques. Signal lines should have 50 Ohm impedance while the package ground leads and package bottom should be connected directly to the ground plane similar to that shown. A sufficient number of via holes should be used to connect the top and bottom ground planes. The evaluation board should be mounted to an appropriate heat sink. The evaluation circuit board shown is available from Hittite upon request.



## **MZ OPTICAL MODULATOR DRIVER, DC - 20 GHz**

### **Device Operation**

These devices are susceptible to damage from Electrostatic Discharge. Proper precautions should be observed during handling, assembly and test.

The input to this device should be AC-coupled. To provide the typical 8Vp-p output voltage swing, a 1.2Vp-p AC-coupled input voltage swing is required.

### **Device Power Up Instructions**

1. Ground the device
  2. Set V<sub>gg</sub> to -2V (no drain current)
  3. Set V<sub>ctl</sub> to +1V (no drain current)
  4. Set V<sub>dd</sub> to +5V (no drain current)
  5. Adjust V<sub>gg</sub> for I<sub>dd</sub> = 140mA
- V<sub>gg</sub> may be varied between -1V and 0V to provide the desired eye crossing point percentage (i.e. 50% crosspoint) and a limited cross point control capability.
  - V<sub>dd</sub> may be increased to +7V if required to achieve greater output voltage swing.
  - V<sub>ctl</sub> may be adjusted between +2V and +0V to vary the output voltage swing.

### **Device Power Down Instructions**

1. Reverse the sequence identified above in steps 1 through 4.



**MZ OPTICAL MODULATOR  
DRIVER, DC - 20 GHz**

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